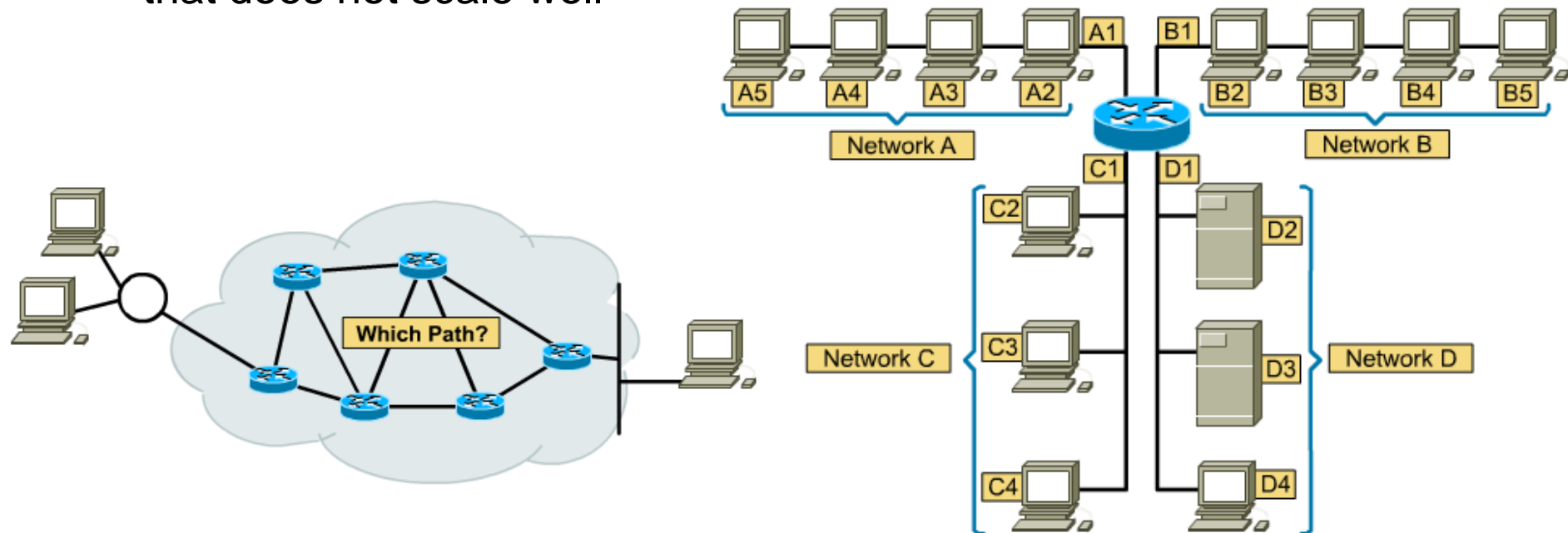# IP Addressing
Part 1

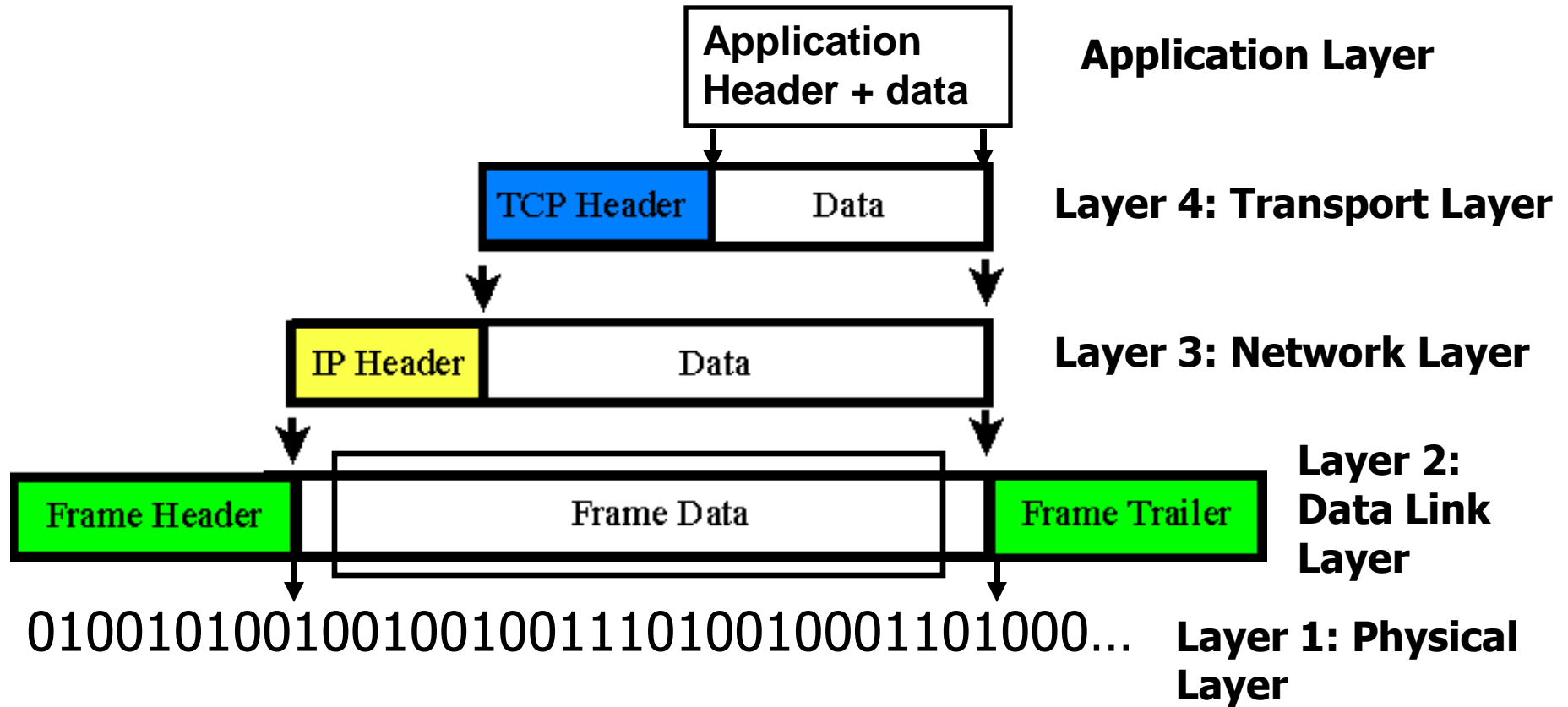**Cabrillo College**

CIS 81 and CST 311

Rick Graziani

Spring 2006
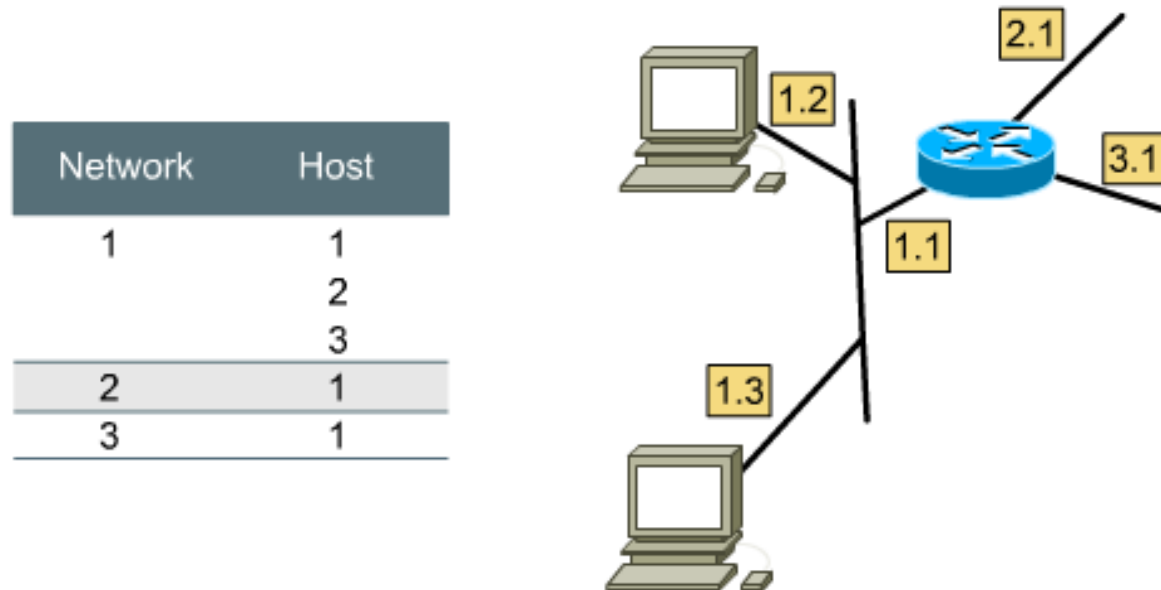
Identifying Network Users

- The **network layer** is responsible for *moving data through a set of networks.*

- **Protocols** that support *network layer* use *hierarchical addressing*

- **Protocols** that have **no** *network layer* only work on *small internal networks.*

- **Protocols** that have **no** *network layer* use a *flat addressing scheme* that does not scale well

Data Encapsulation Example

Application Header + data	**Application Layer**

TCP Header	Data	**Layer 4: Transport Layer**

IP Header	Data	**Layer 3: Network Layer**

Frame Header	Frame Data	Frame Trailer	**Layer 2: Data Link Layer**

010010100100100100111010010001101000… **Layer 1: Physical Layer**

Addressing: Network & Host

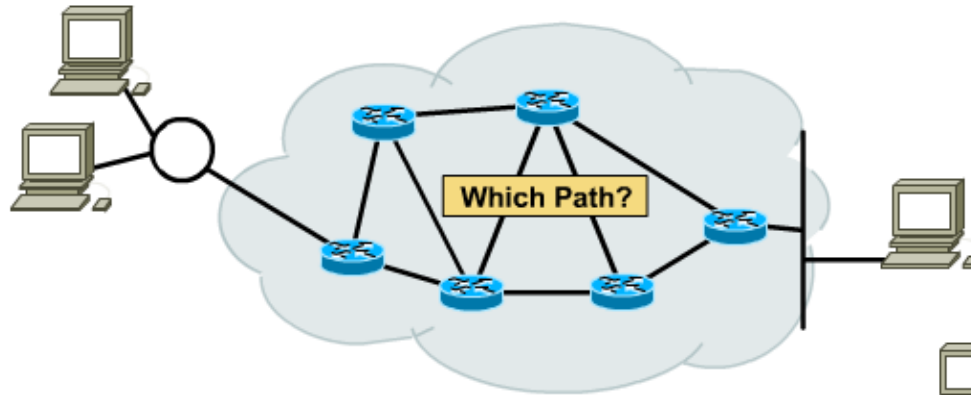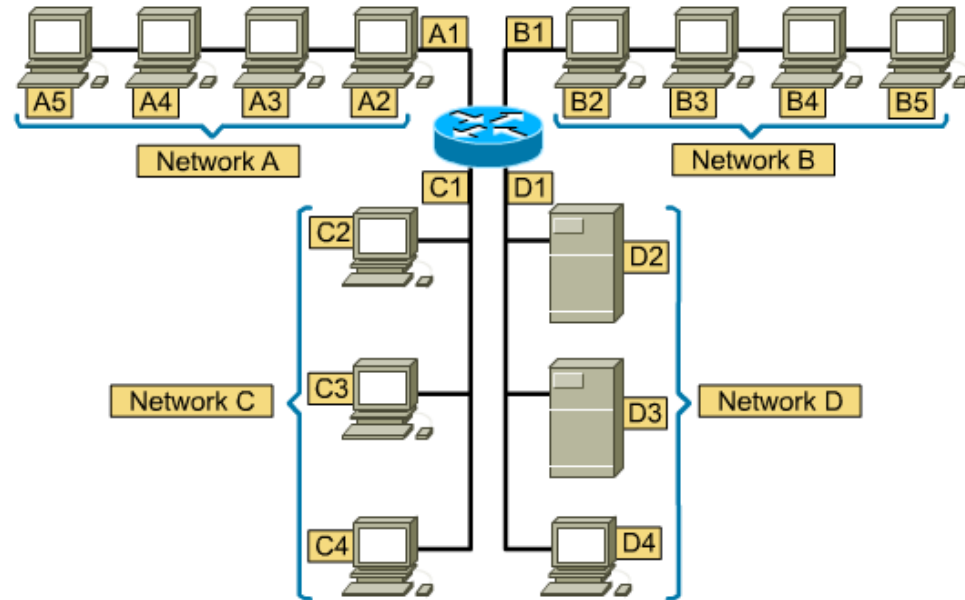| Network	Host
1	1
	2
	3
2	1
3	1

- **Network address** help to identify route through the network cloud
- Network address divided into two parts:
  – **Network**
  – **host**
- Different network protocols have their own methods of dividing the network address into network and host portions. (We will only discuss IP.)

Path Determination

Which Path?

Path determination is determined by Routing Protocols (OSPF, EIGRP, RIP, etc.) - later

A5 A4 A3 A2 A1 B1 B2 B3 B4 B5

Network A

Network B

C1 D1

C2 D2
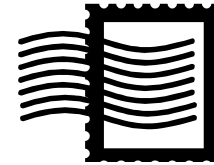
Network C C3 D3 Network D

C4 D4

Network Addressing: Network & Host

- Phone numbers are similar to network addresses
  - Area Code / Phone Number
  - 831 – 479-5783

  - 831 → Network Portion
  - 479-5783 → Host Portion

  - 831 → Santa Cruz / Monterey Counties
  - 479-5783 → Rick Graziani, Cabrillo College

Network Addressing: Network & Host

```
Your Name
123 Main Street
Anytown, ST 12345


            Rick Graziani

            Cabrillo College

            6500 Soquel Drive

            Aptos, CA 95003
```
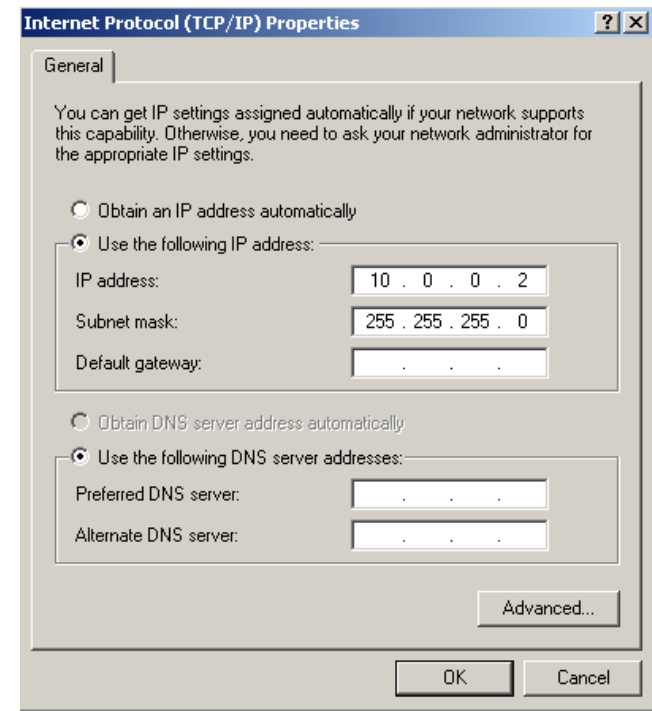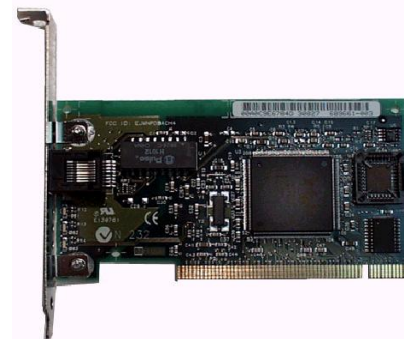
ZIP codes direct your mail to your local post office and your neighborhood. The street address then directs the carrier to your home.

Computer Mobility

Layer 2 (Ethernet) and Layer 3 (IP) Addresses are needed:

- Layer 2 / MAC address
  - Physically burned into the NIC
  - Doesn't change
  - The device's real identity

- Layer 3 / Protocol address
  - Set with software
  - The device's "mailing" address
  - Needs to change when device is moved

What is the MAC and IP Address on my computer?

Flat versus Hierarchical

- Layer 2 - Flat addressing schemes
    - Next available
    - Social Security Number
    - MAC addresses

- Layer 3 - Hierarchical addressing schemes
    - Phone numbers
    - ZIP codes
    - IP addresses

Layer 2 Addresses = Flat Addressing

If the Internet was a flat network with only layer 2 addresses, switches would need to know the millions of layer 2 host addresses or broadcast the frame as an unknown unicast.

Layer 3 Addresses = Organized by Network

Cabrillo

UCSC

Your ISP

- **Layer 3 Addresses** are organized by network.
- To know the layer 3 address, means you know what network this packet belongs to.
- **Routers** maintain lists of layer 3 network addresses to route the packet to the right network.
- Layer 2 addresses are still used!
- Hosts will have both Layer 2 and Layer 3 addresses.
- We will see how these work together a little later.

IP Addressing Scheme

NETWORK	HOST
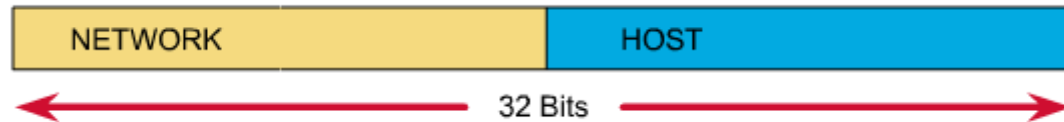
← 32 Bits →

IP Addresses are **32 bits**.

Where the network part ends ant the host part begins depends on the subnet mask (coming).

1 0 0 0 0 0 1 1 0 1 1 0 1 1 0 0 0 1 1 1 1 0 1 0 1 1 0 0 1 1 0 0

← 32 Bits →

Divide into four 8 bit sections (octets).

10000011	01101100	01111010	11001100

←8 Bits→ ←8 Bits→ ←8 Bits→ ←8 Bits→
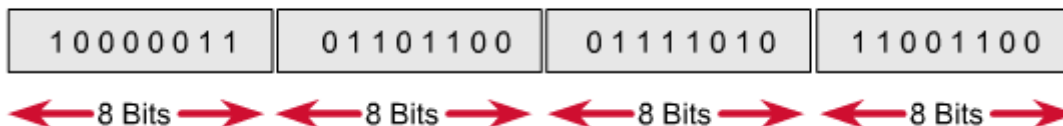
Convert from binary to decimal.

131	.	108	.	122	.	204

←8 Bits→ ←8 Bits→ ←8 Bits→ ←8 Bits→

IP – Layer 3

0			15 16	31
4-bit Version	4-bit Header Length	8-bit Type Of Service (TOS)	16-bit Total Length (in bytes)	
16-bit Identification			3-bit Flags	13-bit Fragment Offset
8 bit Time To Live TTL		8-bit Protocol	16-bit Header Checksum	
32-bit Source IP Address				
32-bit Destination IP Address				

Options (if any)

Data

Application Header + data

TCP Header	Data

IP Header	Data

Frame Header	Frame Data	Frame Trailer

IP Addresses

- The 32 bits of an IP address are grouped into 4 bytes:

10101001110001110100010110001001

10101001 11000111 01000101 10001001

- We use **dotted notation** (or **dotted decimal notation**) to represent the value of each byte (octet) of the IP address in decimal.

10101001 11000111 01000101 10001001
169   .   199   .   69   .   137

IP Addresses

An IP address has two parts:

– **network number**

– **host number**

Which bits refer to the network number?

Which bits refer to the host number?

NETWORK	HOST

← 32 Bits →
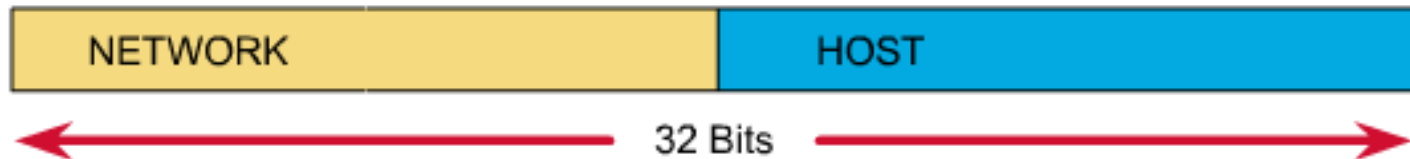
IP Addresses

Answer:

- Current technology - **Classless IP Addressing**
  - The **subnet mask** determines the network portion and the host portion.
  - Value of first octet does NOT matter (older classful IP addressing)
  - Hosts and Classless Inter-Domain Routing (CIDR).
  - Classless IP Addressing is what is used within the Internet and in most internal networks.

- Older technology - **Classful IP Addressing (later)**
  - **Value of first octet** determines the network portion and the host portion.
  - Used with classful routing protocols like RIPv1.
  - The Cisco IP Routing Table is structured in a classful manner (sem2).

Classless IP Addressing

- This chapter discusses Classless IP Addressing
- Next we will discuss Classful IP Addressing

IP Addressing

192.168.1.0/24   192.4.0.0/24

10.2.0.0/16   172.0.0.0/8
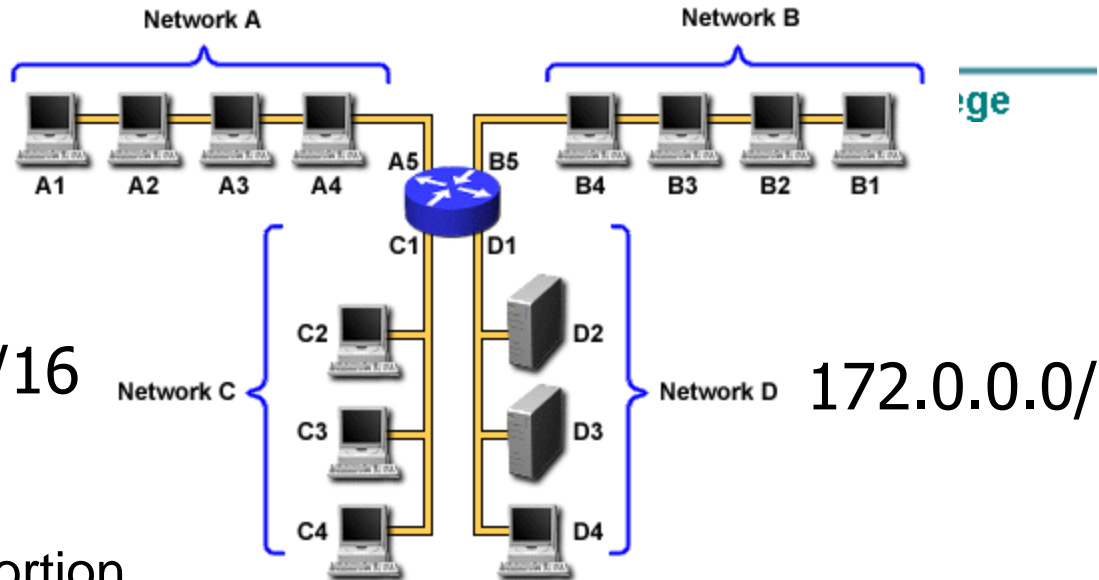
- Network ID or Network Portion
  - Host on a network can only communicate directly with devices if they have the same network ID, i.e. same network or same subnet.
  - The **subnet mask** determines the network portion and the host portion.
  - Network address cannot be used as an address for any device that is attached to the network, such as hosts, router interfaces, etc. (coming)

Using the subnet mask

NETWORK	HOST

← 32 Bits →
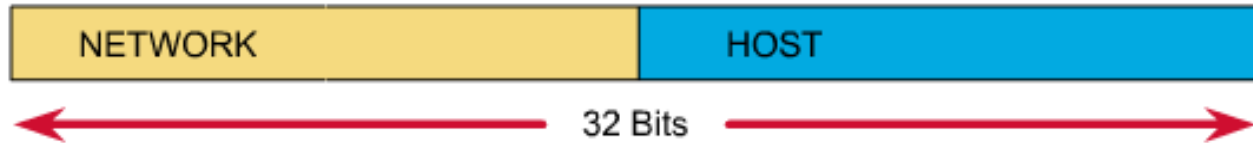
- The **subnet mask** is what tells you what part of the IP address is the network portion and which part of the IP address is the host portion.

- When getting an IP address, either a host address or a network address, from an ISP (Internet Service Provider), they also provide you with a subnet mask, which is known as the **Base Network Mask**.

- As you will see in a moment, you can modify this subnet mask (make it longer), to subnet your own network further.

Subnet Masks - Binary

	1st octet	2nd octet	3rd octet	4th octet
172.0.0.0	**Network**	Host	Host	Host
Subnet Mask	**11111111**	00000000	00000000	00000000
192.4.0.0	**Network**	**Network**	Host	Host
Subnet Mask	**11111111**	**11111111**	00000000	00000000
192.168.1.0	**Network**	**Network**	**Network**	Host
Subnet Mask	**11111111**	**11111111**	**11111111**	00000000

- A "1" bit in the subnet mask means that the corresponding bit in the IP address should be read as a network number

- A "0" bit in the subnet mask means that the corresponding bit in the IP address should be read as a host bit.

Subnet Masks – dotted decimal

	1st octet	2nd octet	3rd octet	4th octet
172.0.0.0	**Network**	Host	Host	Host
Subnet Mask: 255.0.0.0 or /8	**255**	0	0	0

	1st octet	2nd octet	3rd octet	4th octet
192.4.0.0	**Network**	**Network**	Host	Host
Subnet Mask: 255.255.0.0 or /16	**255**	**255**	0	0

	1st octet	2nd octet	3rd octet	4th octet
192.168.1.0	**Network**	**Network**	**Network**	Host
Subnet Mask: 255.255.255.0 or /24	**255**	**255**	**255**	0

- /n "slash" tells us how many "1" bits are in the subnet mask.
- Subnet masks do **not** have to end on "natural octet boundaries"
- **Network Addresses have all zeros in the host portion of the address.**

Subnet Masks

	1st octet	2nd octet	3rd octet	4th octet
172.0.0.0	Network	Host	Host	Host
Subnet Mask: 255.0.0.0 or /8	11111111	00000000	00000000	00000000
192.4.0.0	Network	Network	Host	Host
Subnet Mask: 255.255.0.0 or /16	11111111	11111111	00000000	00000000
192.168.1.0	Network	Network	Network	Host
Subnet Mask: 255.255.255.0 or /24	11111111	11111111	11111111	00000000

- /n "slash" tells us how many "1" bits are in the subnet mask.
- Subnet masks do **not** have to end on "natural octet boundaries"

Subnet Masks – dotted decimal

	1st octet	2nd octet	3rd octet	4th octet
192.4.0.0	**Network**	**Network**	Host	Host
Subnet Mask: 255.255.0.0 or /16	**255**	**255**	0	0

10.2.0.0	**Network**	**Network**	**Network**	Host
Subnet Mask: 255.255.255.0 or /24	**255**	**255**	**255**	0

- **Need to check the mask as an octet in the network address can be a 0.**

Why the mask matters: Number of hosts!

Subnet Mask:

	1st octet	2nd octet	3rd octet	4th octet
255.0.0.0 or /8	Network	Host	Host	Host
255.255.0.0 or /16	Network	Network	Host	Host
255.255.255.0 or /24	Network	Network	Network	Host

- **Subnet masks do <u>not</u> have to end on "natural octet boundaries"**

Subnet: 255.0.0.0 (/8)

Network	Host	Host	Host

8 bits   8 bits   8 bits

With 24 bits available for hosts, there a 2^{24} possible addresses. That's 16,777,216 nodes!
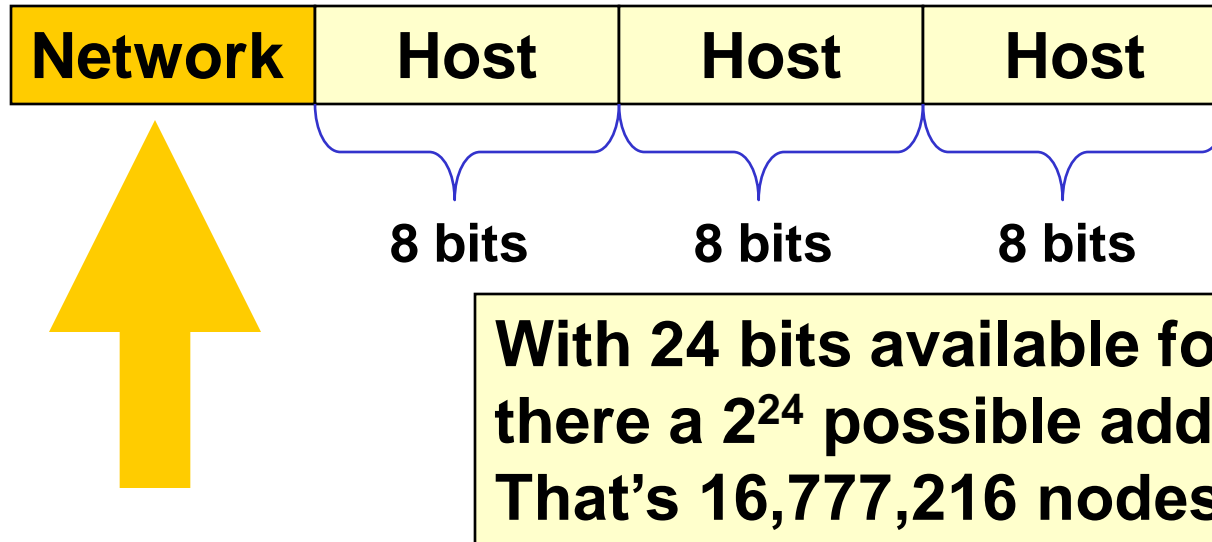
- Only large organizations such as the military, government agencies, universities, and large corporations have networks with these many addresses.

- Example: A certain cable modem ISP has 24.0.0.0 and a DSL ISP has 63.0.0.0

Subnet: 255.255.0.0 (/16)

Network	Network	Host	Host

8 bits   8 bits

With 16 bits available for hosts, there a 2^{16} possible addresses. That's 65,536 nodes!
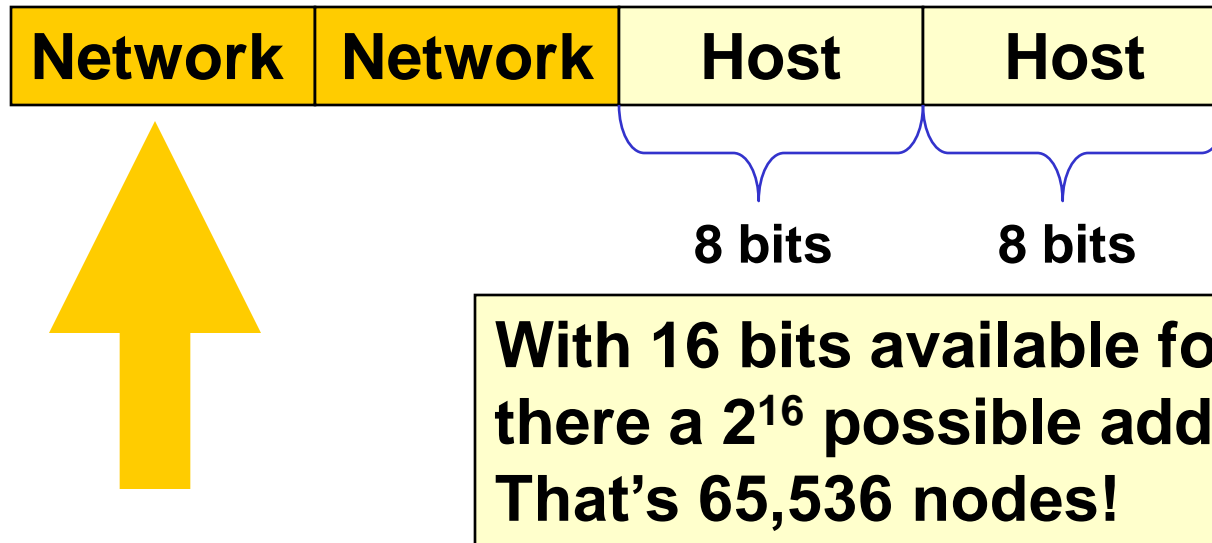
- 65,534 host addresses, one for network address and one for broadcast address.

Subnet: 255.255.255.0 (/24)

Network	Network	Network	Host
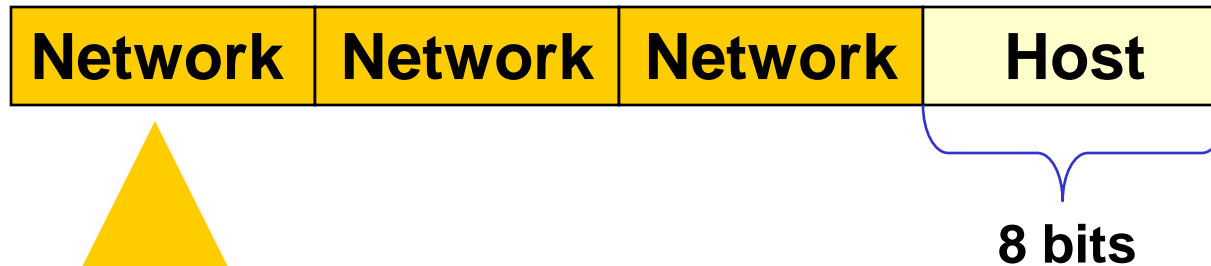
8 bits

With 8 bits available for hosts, there a 2^8 possible addresses. That's 256 nodes!

- 254 host addresses, one for network address and one for broadcast address.

IP Addresses

NETWORK	HOST

← 32 Bits →
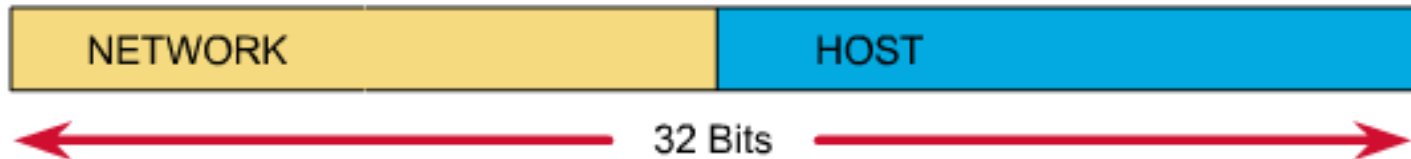
There is a tradeoff between:

- The number of network bits and the number of networks you can have…

AND

- The number of HOST bits and the number of hosts for each network you can have.

This will be examined more closely, later.

- Network address cannot be used as an address for any device that is attached to the network, such as hosts, router interfaces, etc. (coming)
- Network Address: All zeros in the host portion of the address.
  - Note: Need to check the mask as the network address include 0 bits.

Subnet Masks – Your Turn!

- Underline the network portion of each address:

Network Address	Subnet Mask
172.0.0.0	255.0.0.0
172.16.0.0	255.255.0.0
192.168.1.0	255.255.255.0
192.168.0.0	255.255.0.0
192.168.0.0	255.255.255.0
10.1.1.0	/24
10.2.0.0	/16
10.0.0.0	/16

- What is the other portion of the address?

Subnet Masks – Your Turn!

- Underline the network portion of each address:

Network Address	Subnet Mask
<u>172</u>.0.0.0	255.0.0.0
<u>172.16</u>.0.0	255.255.0.0
<u>192.168.1</u>.0	255.255.255.0
<u>192.168</u>.0.0	255.255.0.0
<u>192.168.0</u>.0	255.255.255.0
<u>10.1.1</u>.0	/24
<u>10.2</u>.0.0	/16
<u>10.0</u>.0.0	/16

- What is the other portion of the address?
  - Host Addresses

IP Addressing

192.168.1.0   192.4.0.0

Network A   Network B

A1 A2 A3 A4   A5 B5   B4 B3 B2 B1

C1 D1

C2   D2

10.2.0.0   Network C   Network D   172.0.0.0

C3   D3

C4   D4
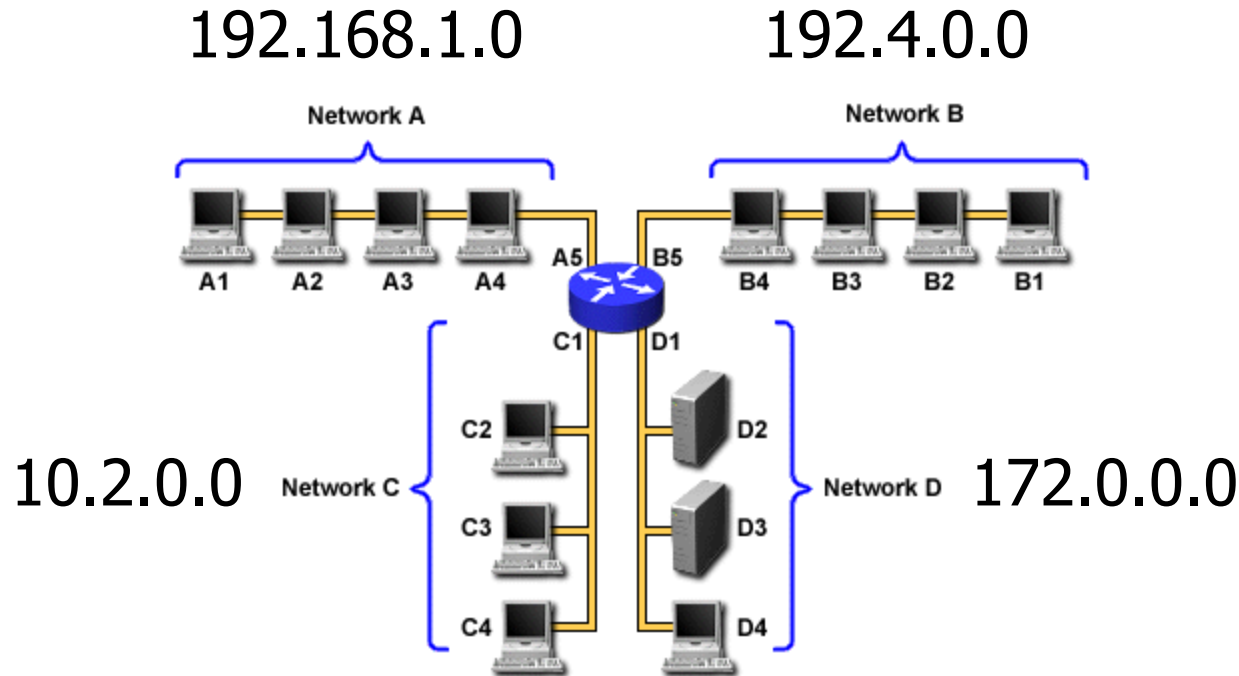
- **Broadcast Address**
  - Used to send data to all devices on the network
  - **All ones in the host portion of the address**
  - All devices pay attention to a broadcast
  - Broadcast addresses cannot be used as an address for any device that is attached to the network.
  - **What are the broadcast addresses for these networks?**

Subnet Masks – Your Turn!

- What is the broadcast address of each network:

Network Address	Subnet Mask	Broadcast Address
172.0.0.0	255.0.0.0	
172.16.0.0	255.255.0.0	
192.168.1.0	255.255.255.0	
192.168.0.0	255.255.0.0	
192.168.0.0	255.255.255.0	
10.1.1.0	/24	
10.2.0.0	/16	
10.0.0.0	/16	

Subnet Masks – Your Turn!

- **What is the broadcast address of each network:**

Network Address	Subnet Mask	Broadcast Address
172.0.0.0	255.0.0.0	172.255.255.255
172.16.0.0	255.255.0.0	172.16.255.255
192.168.1.0	255.255.255.0	192.168.1.255
192.168.0.0	255.255.0.0	192.168.255.255
192.168.0.0	255.255.255.0	192.168.0.255
10.1.1.0	/24	10.1.1.255
10.2.0.0	/16	10.2.255.255
10.0.0.0	/16	10.0.255.255

Subnet Masks – Your Turn!

- **Convert these addresses and masks to Binary (to be used later)**

```
172.0.0.0          _____._____._____._____
255.0.0.0          _____._____._____._____
172.255.255.255    _____._____._____._____

172.16.0.0         _____._____._____._____
255.255.0.0        _____._____._____._____
172.16.255.255     _____._____._____._____
```

Subnet Masks – Your Turn!

- Convert these addresses and masks to Binary (to be used later)

```
172.0.0.0          10101100.00000000.00000000.00000000
255.0.0.0          11111111.00000000.00000000.00000000
172.255.255.255    10101100.11111111.11111111.11111111

172.16.0.0         10101100.00010000.00000000.00000000
255.255.0.0        11111111.11111111.00000000.00000000
172.16.255.255     10101100.00010000.11111111.11111111
```

Subnet Masks – Your Turn!

- **Convert these addresses and masks to Binary (to be used later)**

192.168.1.0   _____._____._____._____

255.255.255.0   _____._____._____._____

192.168.1.255   _____._____._____._____

192.168.0.0   _____._____._____._____

255.255.0.0   _____._____._____._____

192.168.255.255   _____._____._____._____

192.168.0.0   _____._____._____._____

255.255.255.0   _____._____._____._____

192.168.0.255   _____._____._____._____

Subnet Masks – Your Turn!

- Convert these addresses and masks to Binary (to be used later)

192.168.1.0	11000000.10101000.00000001.00000000
255.255.255.0	11111111.11111111.11111111.00000000
192.168.1.255	11000000.10101000.00000001.11111111
192.168.0.0	11000000.10101000.00000000.00000000
255.255.0.0	11111111.11111111.00000000.00000000
192.168.255.255	11000000.10101000.11111111.11111111
192.168.0.0	11000000.10101000.00000000.00000000
255.255.255.0	11111111.11111111.11111111.00000000
192.168.0.255	11000000.10101000.00000000.11111111

Subnet Masks – Your Turn!

- Convert these addresses and masks to Binary (to be used later)

10.1.1.0   _____._____._____._____

/24   _____._____._____._____

10.1.1.255   _____._____._____._____

10.2.0.0   _____._____._____._____

/16   _____._____._____._____

10.2.255.255 _____._____._____._____

10.0.0.0   _____._____._____._____

/16   _____._____._____._____

10.0.255.255 _____._____._____._____

Subnet Masks – Your Turn!

- **Convert these addresses and masks to Binary (to be used later)**

```
10.1.1.0          00001010.00000001.00000001.00000000
/24               11111111.11111111.11111111.00000000
10.1.1.255        00001010.00000001.00000001.11111111


10.2.0.0          00001010.00000010.00000000.00000000
/16               11111111.11111111.00000000.00000000
10.2.255.255      00001010.00000010.11111111.11111111


10.0.0.0          00001010.00000000.00000000.00000000
/16               11111111.11111111.00000000.00000000
10.0.255.255      00001010.00000000.11111111.11111111
```

Addressing: Network & Host

192.168.1.0   192.4.0.0

10.2.0.0   172.0.0.0
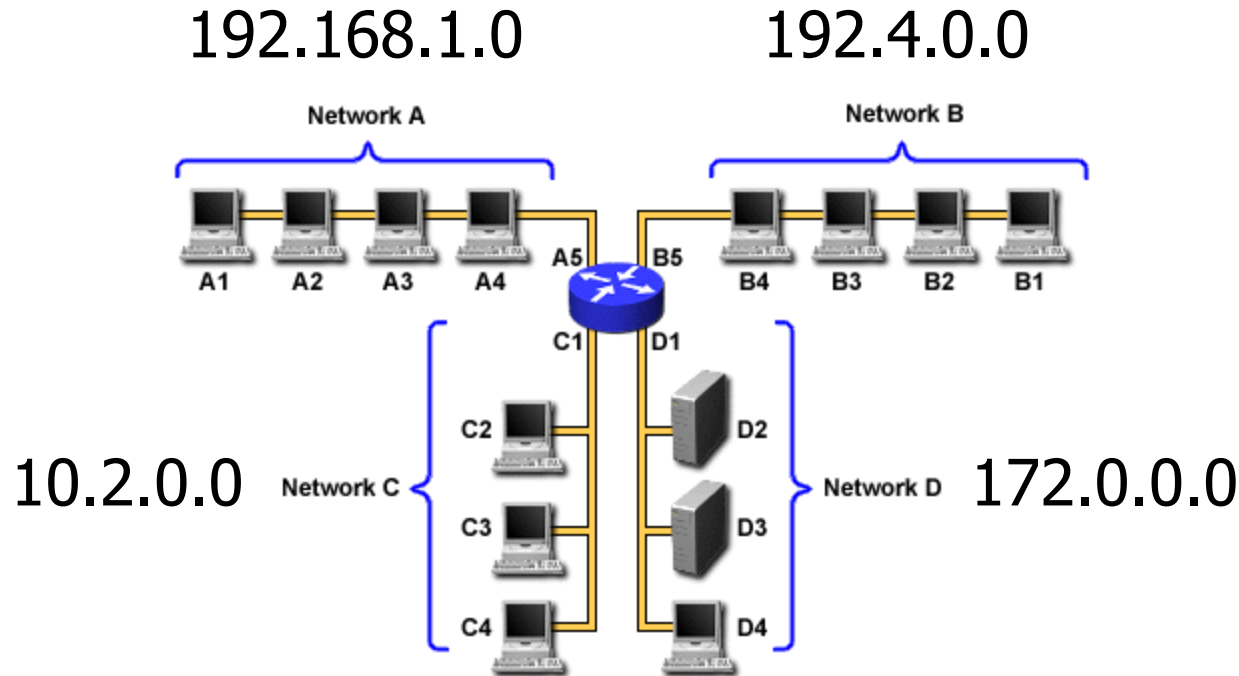
Routers are required when two hosts with
IP addresses on different networks or subnets need to communicate.
- **What are some example Host IP addresses?**

Host Addresses
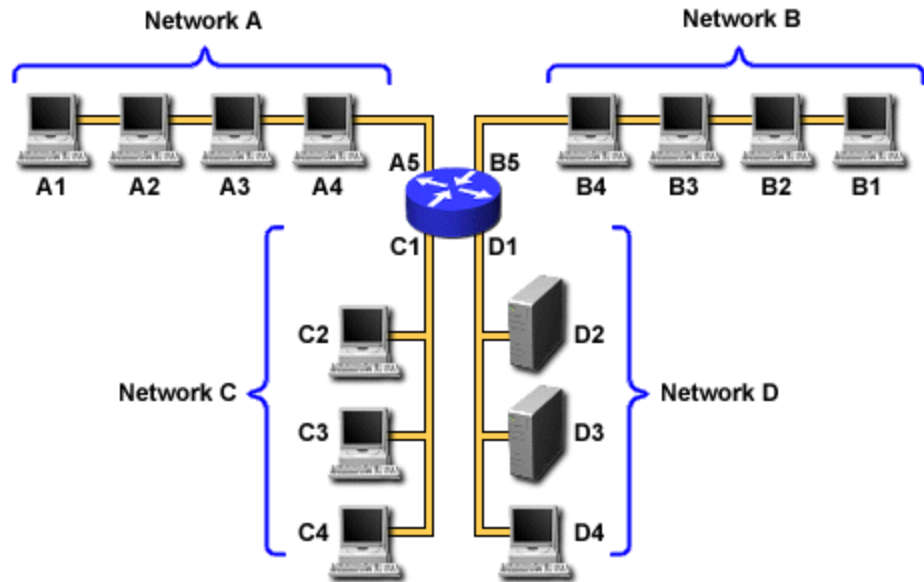
- Network Addresses include a range of HOST IP addresses
- For every network (or subnet) two address cannot be used for HOST IP addresses:
  1. Network Address – The address that represents the network.
  2. Broadcast Address – The address used to communicate with all devices on the network.

Addressing Hosts
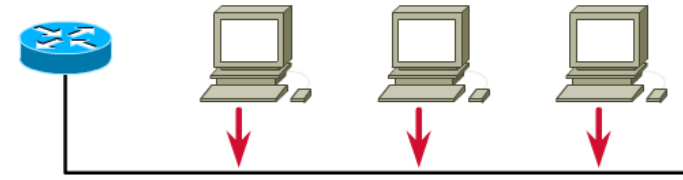
Given the **172.16**.0.0 address with the **255.255.0.0 subnet mask:**

Network	Network	Host	Host
172	16	0	0

One network address, **65,534** hosts, **one** broadcast address.

172	16	0	0	**1 Network Address**
172	16	0	1	**65,534 Host Addresses**
172	16	Etc.	Etc.	$2^{16} - 2$
172	16	255	254	
172	16	255	255	**1 Broadcast Address**

Range of hosts – Your Turn!

- Host addresses are all addresses between the network address and the broadcast address.
- What is the range of host addresses for each network?

Network Address	Subnet Mask	Broadcast Address
172.0.0.0	255.0.0.0	172.255.255.255
172.16.0.0	255.255.0.0	172.16.255.255
192.168.1.0	255.255.255.0	192.168.1.255
192.168.0.0	255.255.0.0	192.168.255.255
192.168.0.0	255.255.255.0	192.168.0.255
10.1.1.0	/24	10.1.1.255
10.2.0.0	/16	10.2.255.255
10.0.0.0	/16	10.0.255.255

Range of hosts – Your Turn!

Network Address	Subnet Mask	Broadcast Address
172.0.0.0	255.0.0.0	172.255.255.255

172.0.0.1 through 172.255.255.254

Network Address	Subnet Mask	Broadcast Address
172.16.0.0	255.255.0.0	172.16.255.255

172.16.0.1 through 172.16.255.254

Network Address	Subnet Mask	Broadcast Address
192.168.1.0	255.255.255.0	192.168.1.255

192.168.1.1 through 192.168.1.254

Network Address	Subnet Mask	Broadcast Address
192.168.0.0	255.255.0.0	192.168.255.255

192.168.0.1 through 192.168.255.254

Network Address	Subnet Mask	Broadcast Address
192.168.0.0	255.255.255.0	192.168.0.255

192.168.0.1 through 192.168.0.254

Range of hosts – Your Turn!

Network Address	Subnet Mask	Broadcast Address
10.1.1.0	/24	10.1.1.255

10.1.1.1 through 10.1.1.254

Network Address	Subnet Mask	Broadcast Address
10.2.0.0	/16	10.2.255.255

10.2.0.1 through 10.2.255.254

Network Address	Subnet Mask	Broadcast Address
10.0.0.0	/16	10.0.255.255

10.0.0.1 through 10.0.255.254

Range of hosts – Your Turn!

- **Host Addresses in binary**

```
172.0.0.0 (net)       10101100.00000000.00000000.00000000
255.0.0.0 (SM)        11111111.00000000.00000000.00000000
172.0.0.1             _____._____._____._____
172.255.255.254       _____._____._____._____
172.255.255.255       10101100.11111111.11111111.11111111
(broadcast)


172.16.0.0 (net)      10101100.00010000.00000000.00000000
255.255.0.0 (SM)      11111111.11111111.00000000.00000000
172.16.0.1            _____._____._____._____
172.16.255.254        _____._____._____._____
172.16.255.255        10101100.00010000.11111111.11111111
(broadcast)
```

Range of hosts – Your Turn!

- **Host Addresses in binary**

```
172.0.0.0 (net)      10101100.00000000.00000000.00000000
255.0.0.0 (SM)       11111111.00000000.00000000.00000000
172.0.0.1            10101100.00000000.00000000.00000001
172.255.255.254      10101100.11111111.11111111.11111110
172.255.255.255      10101100.11111111.11111111.11111111
(broadcast)


172.16.0.0 (net)     10101100.00010000.00000000.00000000
255.255.0.0 (SM)     11111111.11111111.00000000.00000000
172.16.0.1           10101100.00010000.00000000.00000001
172.16.255.254       10101100.00010000.11111111.11111110
172.16.255.255       10101100.00010000.11111111.11111111
(broadcast)
```

Range of hosts – Your Turn!

- **Host Addresses in binary**

```
192.168.1.0 (net)  11000000.10101000.00000001.00000000
255.255.255.0(SM)  11111111.11111111.11111111.00000000
192.168.1.1        _____._____._____._____
192.168.1.254      _____._____._____._____
192.168.1.255      11000000.10101000.00000001.11111111
(broadcast)
```

```
192.168.0.0 (net)  11000000.10101000.00000000.00000000
255.255.0.0 (SM)   11111111.11111111.00000000.00000000
192.168.0.1        _____._____._____._____
192.168.255.254    _____._____._____._____
192.168.255.255    11000000.10101000.11111111.11111111
(broadcast)
```

Range of hosts – Your Turn!

- **Host Addresses in binary**

```
192.168.1.0 (net)   11000000.10101000.00000001.00000000
255.255.255.0(SM)   11111111.11111111.11111111.00000000
192.168.1.1         11000000.10101000.00000001.00000001
192.168.1.254       11000000.10101000.00000001.11111110
192.168.1.255       11000000.10101000.00000001.11111111
(broadcast)


192.168.0.0 (net)   11000000.10101000.00000000.00000000
255.255.0.0 (SM)    11111111.11111111.00000000.00000000
192.168.0.1         11000000.10101000.00000000.00000001
192.168.255.254     11000000.10101000.11111111.11111110
192.168.255.255     11000000.10101000.11111111.11111111
(broadcast)
```

Range of hosts – Your Turn!

- **Host Addresses in binary**

```
192.168.0.0 (net)   11000000.10101000.00000000.00000000
255.255.255.0(SM)   11111111.11111111.11111111.00000000
192.168.0.1         _____._____._____._____
192.168.0.254       _____._____._____._____
192.168.0.255       11000000.10101000.00000000.11111111
(broadcast)
```

Range of hosts – Your Turn!

- **Host Addresses in binary**

192.168.0.0 (net) 11000000.10101000.00000000.00000000
255.255.255.0(SM) 11111111.11111111.11111111.00000000
192.168.0.1 11000000.10101000.00000000.00000001
192.168.0.254 11000000.10101000.00000000.11111110
192.168.0.255 11000000.10101000.00000000.11111111
(broadcast)

Range of hosts – The rest...

Host Addresses in binary

```
10.1.1.0 (net)      00001010.00000001.00000001.00000000
/24    (SM)         11111111.11111111.11111111.00000000
10.1.1.1            00001010.00000001.00000001.00000001
10.1.1.254          00001010.00000001.00000001.11111110
10.1.1.255          00001010.00000001.00000001.11111111
(broadcast)


10.2.0.0 (net)      00001010.00000010.00000000.00000000
/16     (SM)        11111111.11111111.00000000.00000000
10.2.0.1            00001010.00000010.00000000.00000001
10.2.255.254        00001010.00000010.11111111.11111110
10.2.255.255        00001010.00000010.11111111.11111111
(broadcast)
```

Range of hosts – The rest...

- **Host Addresses in binary**

```
10.0.0.0 (net)      00001010.00000000.00000000.00000000
/16      (SM)       11111111.11111111.00000000.00000000
10.0.0.1            00001010.00000000.00000000.00000001
10.0.255.254        00001010.00000000.11111111.11111110
10.0.255.255        00001010.00000000.11111111.11111111
(broadcast)
```

Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries
- Convert these to binary:

Network Address	Subnet Mask
172.1.16.0	255.255.240.0
192.168.1.0	255.255.255.224

Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

```
172.1.16.0          10101100.00000001.00010000.00000000
255.255.240.0       11111111.11111111.11110000.00000000
```

- What is the range of host addresses in dotted-decimal and binary?
- What is the broadcast address?
- How many host addresses?

Subnet Masks: Non-Natural Boundaries

- **Subnet masks do not have to end on natural octet boundaries**

172.1.16.0	10101100.00000001.00010000.00000000
255.255.240.0	11111111.11111111.11110000.00000000
172.1.16.1	10101100.00000001.00010000.00000001
172.1.16.2	10101100.00000001.00010000.00000010
172.1.16.3	10101100.00000001.00010000.00000011
…	
172.1.16.255	10101100.00000001.00010000.11111111
172.1.17.0	10101100.00000001.00010001.00000000
172.1.17.1	10101100.00000001.00010001.00000001
…	
172.1.31.254	10101100.00000001.00011111.11111110

Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

172.1.16.0   10101100.00000001.00010000.00000000

255.255.240.0   11111111.11111111.11110000.00000000

172.1.16.1   10101100.00000001.00010000.00000001

…

172.1.31.254   10101100.00000001.00011111.11111110

172.1.31.255   10101100.00000001.00011111.11111111
(broadcast)

Number of hosts: $2^{12} - 2 = 4,096 - 2 =$ **4,094 hosts**

Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

192.168.1.0	11000000.10101000.00000001.00000000
255.255.255.224	11111111.11111111.11111111.11100000

192.168.1.1	11000000.10101000.00000001.00000001
192.168.1.2	11000000.10101000.00000001.00000010
192.168.1.3	11000000.10101000.00000001.00000011
…	
192.168.1.29	11000000.10101000.00000001.00011101
192.168.1.30	11000000.10101000.00000001.00011110

192.168.1.31 (broadcast)	11000000.10101000.00000001.00011111

Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

192.168.1.0   11000000.10101000.00000001.00000000
255.255.255.224   11111111.11111111.11111111.11100000

192.168.1.1   11000000.10101000.00000001.00000001
…
192.168.1.30   11000000.10101000.00000001.00011110

192.168.1.31   11000000.10101000.00000001.00011111
(broadcast)

Number of hosts: $2^5 - 2 = 32 - 2 = $ 30 hosts

Why Subnet?

Subnets and Subnet Masks

NETWORK	SUBNET	HOST
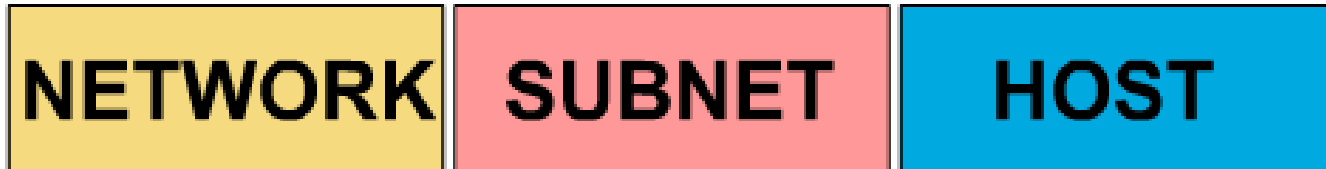
Formalized in 1985, the subnet mask breaks a single network in to smaller pieces.

- A "1" bit in the subnet mask means that the corresponding bit in the IP address should be read as a network number
- A "0" bit in the subnet mask means that the corresponding bit in the IP address should be read as a host bit.
- Allows network administrators to divide their network into small networks or **subnets**.
- Advantages will be discussed later.

What is subnetting?

Network	Network	Host	Host
172	16	0	0

↓

Network	Network	Subnet	Host
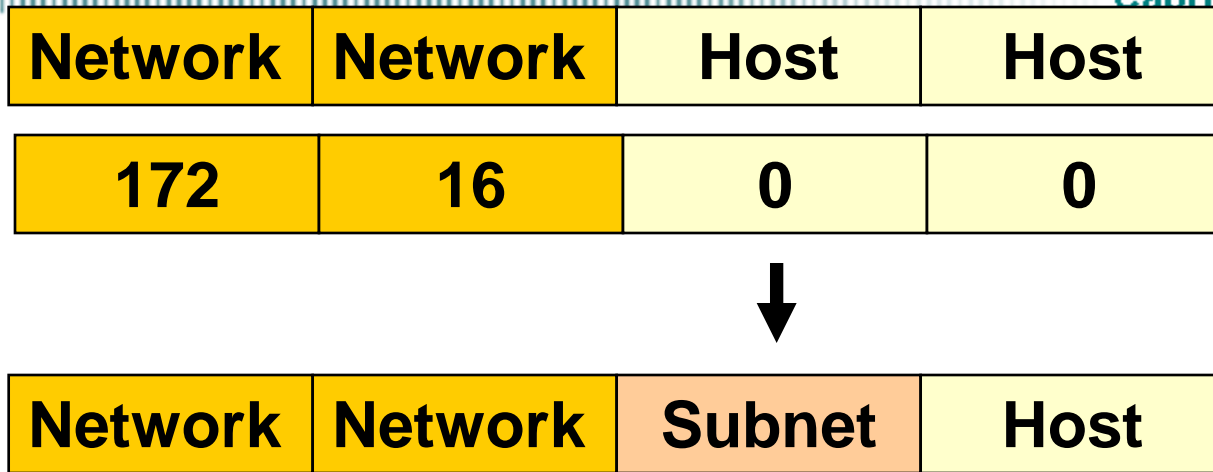
- Subnetting is the process of borrowing bits from the HOST bits, in order to divide the larger network into small subnets.
- Subnetting does **NOT** give you more hosts, but actually costs you hosts.
- You lose two host IP Addresses for each subnet, one for the subnet IP address and one for the subnet broadcast IP address.
- You lose the last subnet and all of it's hosts' IP addresses as the broadcast for that subnet is the same as the broadcast for the network.
- In older technology, you would have lost the first subnet, as the subnet IP address is the same as the network IP address. (This subnet can be used in most networks.)

Analogy

98 Apples (100 – 2)

Before subnetting:

- In any network (or subnet) we can not use all the IP addresses for host addresses.

- We lose two addresses for every network or subnet.

1. Network Address - One address is reserved to that of the network. For Example: 172.16.0.0 /16

2. Broadcast Address – One address is reserved to address all hosts in that network or subnet. For Example: 172.16.255.255

This gives us a total of **65,534** usable hosts

Analogy

98 Apples (100 – 2)
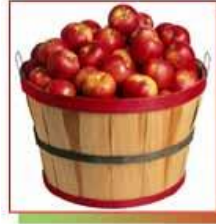
10   10   10
10   10   10
10   10   10
                10

- It is the same as taking a barrel of 100 apples and dividing it into 10 barrels of 10 apples each.

9 barrels x 8 apples = 72 apples

**98 Apples
(100 − 2)** →

8 (less 2)   8 (less 2)   8 (less 2)

8 (less 2)   8 (less 2)   8 (less 2)

8 (less 2)   8 (less 2)   8 (less 2)

Cab
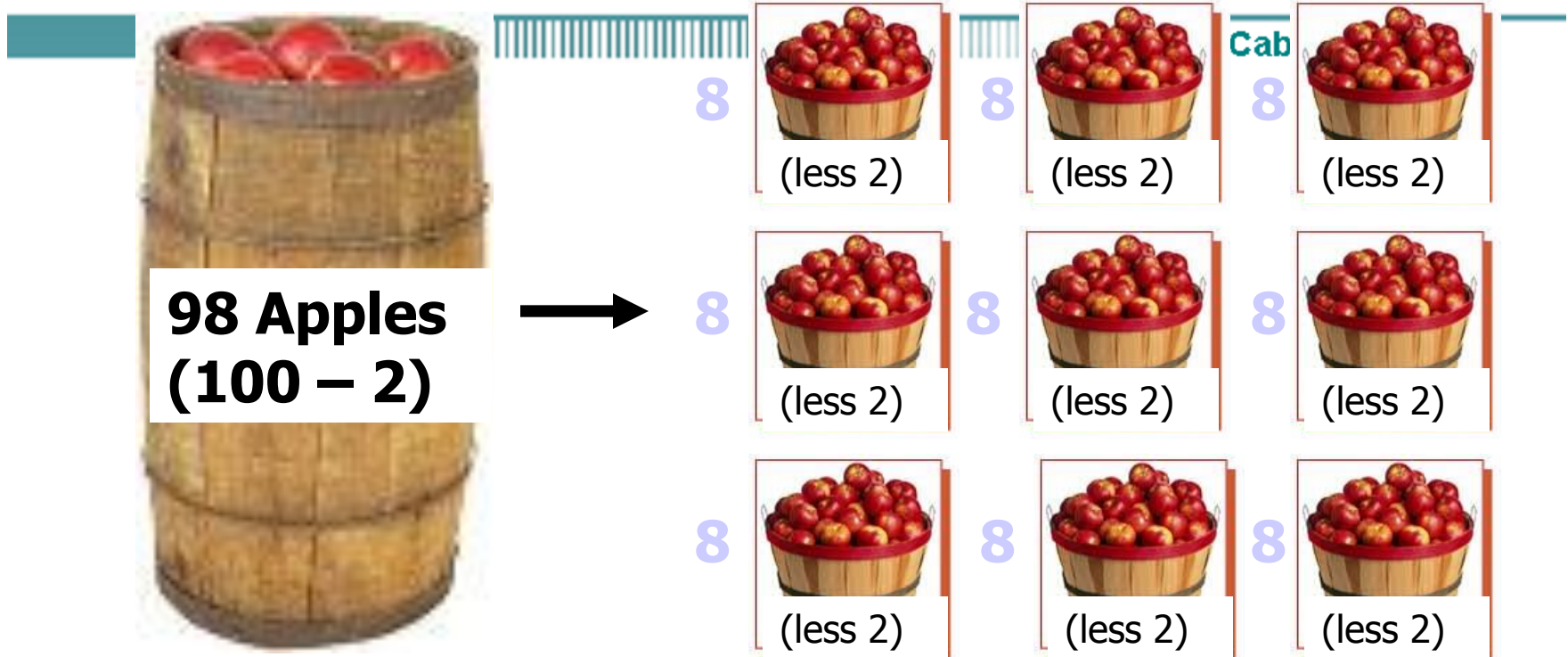
- However, in subnetting we will see that we lose two apples per subnet, one for the network address and one for the broadcast address.

X

- We also lose the entire last basket of apples, subnet, as it contains the broadcast address for the entire network.

- In older networks, we also lost the first basket, subnet, as it contained the address of the entire network, but this is usually no longer the case.

Subnet Example

Network address **172.16**.**0.0**

Base Network Mask **255.255.0.0** or /16

Base Network Mask:
255.255.0.0 or /16

Network	Network	Host	Host
11111111	11111111	00000000	00000000

Subnet Mask:
255.255.255.0 or /24

Network	Network	Subnet	Host
11111111	11111111	11111111	00000000

- Applying a mask which is larger than the major network subnet mask, will divide your network into subnets.
- Major network mask is 255.255.0.0 or /16
- Subnet mask used here is 255.255.<u>255</u>.0 or /24

Subnet Example

Network address **172.16**.**0.0 with /16 Base Network Mask**
Using Subnets: **Subnet Mask 255.255.255.0 or /24**

Network	Network	Subnet	Host
172	16	0	0
172	16	1	0
172	16	2	0
172	16	3	0
172	16	Etc.	0
172	16	254	0
172	16	255	0

Subnets Addresses

255 Subnets

$2^8 - 1$

Cannot use last subnet as it contains broadcast address

Subnet Example

Network address **172.16**.**0.0 with /16 Base Network Mask**

Using Subnets: **Subnet Mask 255.255.255.0 or /24**

What is the range of hosts per subnet and the broadcast address for each subnet?

Network	Network	Subnet	Host
172	16	0	Host
172	16	1	Host
172	16	2	Host
172	16	3	Host
172	16	Etc.	Host
172	16	254	Host
172	16	255	Host

Subnets

255 Subnets

$2^8 - 1$

Cannot use last subnet as it contains broadcast address

Subnet Example

Network address **172.16**.**0.0 with /16 Base Network Mask**

Using Subnets: **Subnet Mask 255.255.255.0 or /24**

Network	Network	Subnet	Hosts			Broadcast
172	16	0	1	→	254	255
172	16	1	1	→	254	255
172	16	2	1	→	254	255
172	16	3	1	→	254	255
172	16	Etc.	1	→	254	255
172	16	254	1	→	254	255

Network	Network	Subnet	Hosts
172	16	255	Host

Each subnet has 254 hosts, $2^8 - 2$

Subnet Example

With NO subnetting:

Network	First Host	Last Host	Broadcast
172.16.0.0	172.16.0.1	172.16.255.254	172.16.255.255

- 65,534 host addresses, one for network address and one for broadcast address.

With subnetting:

Network	First Host	Last Host	Broadcast
172.16.0.0	172.16.0.1	172.16.0.254	172.16.0.255
172.16.1.0	172.16.1.1	172.16.1.254	172.16.1.255
172.16.2.0	172.16.2.1	172.16.2.254	172.16.2.255
172.16.3.0	172.16.3.1	172.16.3.254	172.16.3.255
172.16.4.0	172.16.4.1	172.16.4.254	172.16.4.255
172.16.5.0	172.16.5.1	172.16.5.254	172.16.5.255
172.16.6.0	172.16.6.1	172.16.6.254	172.16.6.255
172.16.7.0	172.16.7.1	172.16.7.254	172.16.7.255
…			
172.16.254.0	172.16.254.1	172.16.254.254	172.16.15.255
172.16.255.0	172.16.255.1	172.16.255.254	172.16.255.255

With subnetting:

Network	First Host	Last Host	Broadcast	Hosts
172.16.0.0	172.16.0.1	172.16.0.254	172.16.0.255	254
172.16.1.0	172.16.1.1	172.16.1.254	172.16.1.255	254
172.16.2.0	172.16.2.1	172.16.2.254	172.16.2.255	254
172.16.3.0	172.16.3.1	172.16.3.254	172.16.3.255	254
172.16.4.0	172.16.4.1	172.16.4.254	172.16.4.255	254
172.16.5.0	172.16.5.1	172.16.5.254	172.16.5.255	254
172.16.6.0	172.16.6.1	172.16.6.254	172.16.6.255	254
172.16.7.0	172.16.7.1	172.16.7.254	172.16.7.255	254
172.16.8.0	172.16.8.1	172.16.8.254	172.16.8.255	254
172.16.9.0	172.16.9.1	172.16.9.254	172.16.9.255	254
…				
172.16.254.0	172.16.254.1	172.16.254.254	172.16.254.255	254
172.16.255.0	172.16.255.1	172.16.255.254	172.16.255.255	254

```
                                                      ---
                                                   64,770
```

```
Total address = 65,536 - 256 (last subnet) = 65,280
              = 65,280 - 510 (2 hosts per other 255 subnets)
              = 64,770
```

With subnetting:

Network	First Host	Last Host	Broadcast
172.16.0.0	172.16.0.1	172.16.0.254	172.16.0.255
172.16.255.0	172.16.255.1	172.16.255.254	172.16.255.255

Major Network Address: 172.16.0.0

Major Network Mask: 255.255.0.0

Major Network Broadcast Address: 172.16.255.255

Subnet Mask: 255.255.255.0

First Subnet (This is typically used):

Subnet Address: 172.16.0.0

Subnet Broadcast Address: 172.16.0.255

Last Subnet (This is typical not used):

Subnet Address: 172.16.255.0

Subnet Broadcast Address: 172.16.255.255

End of Part 1

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- End of Part 1
- MORE TO FOLLOW!

IP Addressing
Part 1

Cabrillo College

CIS 81 and CST 311

Rick Graziani

Spring 2006